REMARKS

Newly added claims 4 and 5 find support at page 7, lines 2-5 and at page 9, lines 5-8. The limitation of new claims 8 and 10 is described at page 6, lines 19-21 of the original specification. Claim 1 has been amended to place it in somewhat better English form.

The "Substitute Specification and Abstract" submitted herewith contains no new matter. In order that the examiner can satisfy himself in this regard, also submitted herewith is a marked-up copy of the original Specification and Abstract from which the "Substitute Specification and Abstract" was typed.

Responsive to paragraph 1 of the office action, a form PTO-1449 is attached hereto.

The examiner's explanation set forth in paragraph 2 of the office action has been noted.

Responsive to paragraph 3 of the office action a new Fig. 1 is submitted herewith as a separate paper and a copy is attached hereto. The examiner will note that Fig. 1 has been labeled "Prior Art."

Responsive to paragraphs 4 and 5 of the office action, the Specification and Abstract have been revised to place them in better in English form and to place the Abstract into compliance with our rules of practice.

The rejection for obviousness as set forth in paragraphs 6-8 of the office action is respectfully traversed. In combining a feature of Comby with the structure of Lemonnier, the examiner is improperly combining parts of devices which operate very differently. In Lemonnier, outputs through both the upper electrodes and the lower electrodes serve as inputs to "an electronic processing circuit for forming a pixel detector" (column 2, lines 37-40). In contradistinction, in Comby each of the needle-like anodes is independent and the output of each is taken as a separate signal. In Comby, signals are output only by the anodes. Of course, if a number of the anodes of Comby were located on the strip anode as in the examiner's hypothetical, they would no longer be independent from one another and would no longer generate separate signals as contemplated by Comby.

The examiner characterizes the hypothetical combination as having the "columnar anode electrodes planted on the anode strips 6 (as the anodes 3 of Comby et al are planted on the means 18)." However, if one were to put the columnar anode electrodes of Comby on anode strip 6 of Lemonnier, the result would not "as the anodes 3 of Comby are planted on the means 18." In Comby the "thread-like anodes 3" are insulated from each other (column 3, lines 17 and 18) and, as noted above, "are independent from one another" (column 5, lines 9-26). Thus, in the examiner's hypothetical the anodes would neither be insulated from one another nor independent from one another as in Comby. Also note that, as the examiner stated, the anodes 3 of Comby are planted on means 18. Note that means 18 is exterior to the gas cell in Comby whereas the anodes strips 6 of Lemonnier are internal to the gas cell. Thus, the hypothetical combination envisioned by the examiner involves far more than mere combination of the anodes of Comby

and the structure of Lemonnier.

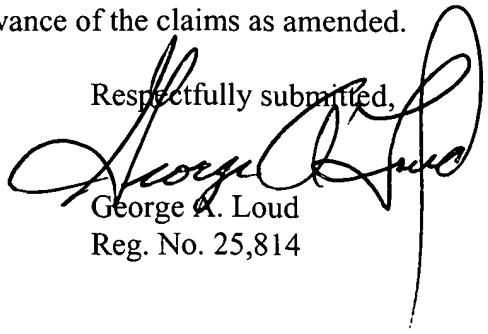
Also note that Lemonnier repeatedly stresses the need for "a substantially uniform electric field." See, for example, column 2, lines 4-8, column 3, lines 61-62 and the claims. In contradistinction, in Comby the electric field is strongest "in the vicinity of the anode points."

New claims 5-8 serve to further distinguish the present invention from the examiner's hypothetical combination because Lemonnier has no "drift electrode" and because both Lemonnier and Comby apply a voltage to the cathode.

Claims 8, 10 and 11 define the columnar anodes as having a height approximating the thickness of the substrate and, therefore, the distal ends of the anodes cannot be recessed "with respect to the insulating support face, so as to provide the photon insulation of each of said anodes," quoting from column 2, lines 34-37 of Comby. Also see column 3, lines 30 and 31 and column 5, lines 34-36 of Comby.

In conclusion, it is respectfully requested that the examiner reconsider the rejection and objections of record with a view toward allowance of the claims as amended.

Respectfully submitted,



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DESCRIPTION

PARTICLE BEAM IMAGE DETECTOR EMPLOYING GAS AMPLIFICATION ATTAINED BY PIXEL-TYPE ELECTRODES

TECHNICAL FIELD

The present invention relates to a particle beam image detector employing gas amplification attained by pixel-type electrodes.

BACKGROUND ART

The present inventors have previously developed, as one type of detector, an MSGC (Micro Strip Gas Chamber), which is a gas-amplification-type particle beam image detector which provides realizing high position resolution and high incident particle tolerance and which has contains strip-type electrodes. Characteristic features of this detector include a very short dead time for a gas amplifier and high position resolution, and the detector has become attracted of keen interest by for virtue of its potential use as a detector for particle beams of high brightness. Presently, tests employing X-rays have confirmed that the detector is free of malfunction under a brightness of 10^7 counts/mm^2·sec and or more.

FIG. 1 is an exploded perspective view of a conventional MSGC.

The MSGC imaging device shown in FIG. 1 has an effective area of 10 cm × 10 cm. Reference numeral 1 denotes

a substrate made of polyimide thin film. Reference numeral 2 denotes an anode strip formed on substrate 1, and reference numeral 3 denotes a strip-shaped cathode electrode. Anode strips 2 and strip-shaped cathode electrodes 3 are juxtaposed alternately.

Reference numeral 4 denotes a base substrate made of ceramic, and reference 5 denotes a back-side electrode formed on the base substrate 4 and placed under the substrate 1. Approximately distance D_1 above the thus-constructed element, a drift plate 6, is provided, to thereby define a chamber for allowing passage of gas therethrough; e.g., a gas containing argon and ethane (see, for example, Japanese patent Application Laid-Open (*kokai*) No. 10-300856).

DISCLOSURE OF THE INVENTION

One critical problem associated with the above-described MSGC encountered during studies for putting the same into practical use is breakage of electrodes resulting from discharge between the electrodes. In the case of the existing MSGC, a voltage is applied between electrodes having a clearance of 50 μm or less. Therefore, when a high voltage is applied in the hope of obtaining increased gas amplification factor, large current flows due to discharge between the electrodes. As a result, it frequently occurs that heat generated from discharge destroys electrode strips, or fragments of the broken electrode strips are deposited onto the surface insulating layer, resulting in malfunction

of the device due to passage of current between the electrodes.

Moreover, since signals generated in the back-side electrodes 5, which are a two-dimensional read out, have a magnitude about 20% that of the signals generated by the anodes located on the surface side, an expensive amplifier must be employed in a circuit for attaining successful read-out of such weak signals, or alternatively, the amplification factor attained as gas amplification must be further improved.

In view of the foregoing, an object of the present invention is to provide a particle beam image detector employing gas amplification attained by pixel-type electrodes, the detector having high sensitivity and electrodes of improved reliability.

In order to achieve the above object, the present invention provides a the following:

[1] A particle beam image detector employing gas amplification attained by pixel-type electrodes, characterized by comprising anode strips formed on one the back surface of a double-sided substrate, columnar anode electrodes which are supported on planted in the anode strips and such that their upper ends penetrate the double-sided substrate so as to extend into apertures in the be exposed to a surface thereof, and strip-shaped cathode electrodes each having an aperture such that each of the corresponding columnar anode electrodes falls therein.

~~[2] The particle beam image detector employing gas amplification attained by pixel-type electrodes as recited in~~

[1] above, wherein each of the anode strips may have a width of about 200 to 400 μm.

~~[3] The particle beam image detector employing gas amplification attained by pixel-type electrodes as recited in [1] above, wherein~~ the anode strips are provided at intervals of about 400 μm, the strip-shaped cathode electrodes each have apertures spaced at intervals of a predetermined distance, the diameter of the aperture being about 200 to 300 μm, and each of the columnar anode electrodes has a diameter of about 40 to 60 μm and a height of about 50 to 150 μm.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded perspective view of a conventional MSGC;

FIG. 2 is a perspective view showing an essential portion of a particle beam image detector employing gas amplification and having attained by pixel-type electrodes, according to one embodiment of the present invention;

FIG. 3 is a plan view showing of the one embodiment of the particle beam image detector employing gas amplification shown in FIG. 2 attained by pixel-type electrodes according to the present invention;

FIG. 4 is an enlarged view of the portion A indicated in FIG. 3;

FIG. 5 illustrates the operational principle of the particle beam image detector of the present invention; and

FIG. 6 shows the relations ip between of voltage applied and ~~versus~~ gas

amplification factor attained by the particle beam image detector of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

BEST MODES FOR CARRYING OUT THE INVENTION

Hereafter, modes for carrying out the present invention will be described with reference to the accompanying drawings.

FIG. 2 is a perspective view showing an essential portion of a particle beam image detector employing gas amplification attained by pixel-type electrodes according to one embodiment of the present invention, FIG. 3 is a plan view thereof, and FIG. 4 is an enlarged view of the portion A indicated in FIG. 3. In FIG. 2, for the sake of easy understanding of the disposition of the anode strips, the lower section of the double-sided printed substrate is depicted to be separated from the upper section. However, it should be noted that the upper and lower sections are not separated, but constitute a unitary, double-sided substrate.

In these FIGs., reference numeral 1 denotes a particle beam image detector, 2 a pixel chamber (300 mm × 300 mm), 11 an anode strip (although width d_1 is 300 μm in the present embodiment, any width falling within the range of about 200 μm to 400 μm may be used), 12 a columnar anode electrode planted in the anode strip 11 (although diameter d_2 is 50 μm, any diameter falling within the range of about 40 μm to 60 μm may be used), 13 a double-sided substrate for a printed circuit having a thickness d_3 of about 100 μm; 14 a strip-shaped cathode electrode formed on one surface of the

substrate 13, and 21 a drift electrode.

As shown in FIG. 2, the particle beam image detector of the present invention includes a double-sided printed circuit substrate 13, strip-shaped cathode electrodes 14 on one surface of the substrate 13, and anode strips 11 on the back surface of the substrate 13. The anode strips 11 are provided with a centerline spacing at a pitch d_5 of 400 μm. The strip-shaped cathode electrodes 14 each have apertures 15 arranged at predetermined intervals. At the center of each aperture 15 is provided a pixel in the form of serving as a columnar anode electrode 12. The pixel is connected to a corresponding anode strip 11 present on the back side. The diameter d_6 of the aperture 15 in the strip-shaped cathode electrode 14 is 250 μm. However, the diameter is not limited thereto and may be assume any value falling within the range of 200 μm to 300 μm.

As described above, in the present embodiment, the pixels ~~serving as~~ anodes 12 each have a diameter of 50 μm; however, the pixels may have a diameter of 40 μm to 60 μm. The anode electrodes 12 are of ~~the columnar~~ a cylindrical shape and have a height d_4 of about 100 μm, approximating the thickness of the double-sided printed substrate 13. ~~The~~ However, the height of the anode electrodes is not limited ~~to the above-mentioned specific height,~~ and may be suitably determined within a range of 50 μm to 150 μm, in accordance with the thickness of the double-sided printed substrate 13.

In actual use of the detector for detecting a particle beam, the double-sided printed substrate 13 is placed in a

pixel chamber 2, i.e., in an inert-gas-based atmosphere. As shown in FIG. 2, a drift electrode 21 is provided at an appropriate position above the substrate 13 (in practice, several mm to several cm above the substrate 13) and parallel to the detector. This arrangement allows image measurement of radioactive rays similar to that attained by MSGC.

FIG. 5 illustrates the operational principle of the particle beam image detector of the present invention.

Electrons e^- produced through ionization of the gas by the incident particle beams drift under the force of a drift field toward a pixel ~~on the substrate, the pixel serving as~~ an anode electrode 12. In the vicinity of the columnar anode electrode 12, by virtue of the presence of a strong electric field formed by a voltage between anode and cathode (e.g., 420 V) and the pointed shape of electrode, gas avalanche amplification of electrons occurs. The ions thus generated quickly drift toward strip-shaped cathode electrodes 14 ~~around the ions~~.

In the course of the above process, electric charges are generated on the columnar anode electrodes 12 and also on the strip-shaped cathodes 14, and these electric charges are observable on the electric circuit. Therefore, observation to determine the anode or cathode strip at which this amplification phenomenon occurs provides information about the position of the incident particle beam. Reading out of signals, circuit design for obtaining two-dimensional images, etc. can be performed by use of those developed for

conventional MSGC.

Characteristic features of the present particle beam image detector are summarized as follows:

(1) Since pixels are used as anodes, strong electric fields can be easily formed, leading to an enhancement of the amplification factor.

(2) Since each cathode surrounds the corresponding anode in a circular fashion, the electric field at the peripheral portion of the cathode is much weaker than that observed at the anode. As a result, flying out of electrons from the cathode is suppressed, and thus discharge does not easily occur.

(3) The electric field between the anode and cathode weakens sharply as a function of distance. Therefore, progress toward discharge may occur only in rare cases.

(4) Between the anode and cathode, an insulator is provided as a substrate. Since the width of the anode strip is larger than the diameter of the aperture of the strip-shaped cathode electrode, and the thickness of the substrate is similar to the radius of the aperture, the direction of the line of electric force is always upward at the insulator surface, eliminating any risk of generating the undesired electrostatic field caused by accumulation of positive ions generated through gas amplification.

(5) Since the present particle beam image detector essentially makes use of techniques for fabricating printed circuit boards, detectors of large area can be produced at

low cost.

(6) In the event of discharge, the detector is not fatally damaged. That is, the only damage the detector would suffer is local breakage (of some pixels).

(7) Since the detector operates under application of voltage to only two terminals, i.e., an anode electrode and a drift electrode, minimum facilities in terms of power supply and wiring are required.

FIG. 6 shows the relations between voltage applied versus gas amplification factor attained by the particle beam image detector of the present invention. In FIG. 6, the x-axis represents voltage (V) applied between the cathode and the anode, the y-axis represents gas amplification factor (logarithmic scale), line "a" represents a characteristic curve according to the present invention, and line "b" represents that obtained from a conventional detector.

As is apparent from FIG. 6, an amplification factor of about 10,000 or thereabouts can be attained by the present invention. Also, when the detector of the present invention was operated for two days continuously at an amplification factor of about 1,000, there was not even a single occurrence of discharge arose. At higher amplification factors, discharge was observed, but only rarely, with no subsequent operational problems.

Although the present invention has been described above with reference to specific embodiments, the invention is not limited to those embodiments. Numerous modifications and

variations of the present invention are possible in light of the spirit of the present invention, and they are not excluded from the scope of the present invention.

As described above in detail, the present invention provides the following advantages and effects among others.

(A) The detector of the invention has the same advantages as those of MSGC. That is, the inventive detector attains a large gain and has improved reliability of electrodes.

(B) Since pixels are used as anodes, strong electric fields can be easily formed, leading to an enhancement of the amplification factor.

(C) Since each cathode surrounds the corresponding anode in a circular fashion, the electric field at the peripheral portion of the cathode is much weaker than that observed at the anode. As a result, flying out of electrons from the cathode is suppressed, and thus discharge does not easily occur.

(D) The electric field between the anode and cathode weakens sharply as a function of distance. Therefore, progress toward discharge may occur only in rare cases.

(E) Between the anode and cathode, an insulator is provided as a substrate. Since the width of the anode strip is larger than the diameter of the aperture of the cathode electrode, and the thickness of the substrate is similar to the radius of the aperture, the direction of the line of electric force is always upward at the insulator surface,

eliminating any risk of generating the undesired, cancelling electrostatic field caused by accumulation of positive ions generated through gas amplification.

(F) Since the present particle beam image detector essentially makes use of techniques for fabricating printed circuit boards, detectors of large area can be produced at low cost.

(G) In the event of discharge, the detector is not fatally damaged. That is, the only damage the detector would suffer is local breakage (of some pixels).

(H) Since the detector operates under application of voltage to only two terminals; i.e., an anode electrode and a drift electrode, minimum facilities in terms of power supply and wiring are required.

INDUSTRIAL APPLICABILITY

The particle beam image detector according to the present invention employing gas amplification attained by pixel-type electrodes is suitable for use in various technical fields involving detection of radioactive rays; i.e., monitoring of radioactive rays, X-ray image analysis, medical ~~use~~ X-ray imaging, and new techniques of gamma-ray imaging.

ABSTRACT

A particle beam image detector employing gas amplification attained by pixel-type electrodes has high sensitivity and improved reliability of electrodes.

Electrons e^- produced through ionization of the gas by the incident particle beams drift under the force of a drift field toward a pixel that is encountered on the way to the surface of the detector, the pixel serving as an anode electrode (12). In the vicinity of the columnar anode electrode ~~by virtue of the presence~~ due to of a strong electric field ~~formed by a voltage~~ between anode and cathode ~~being around 420 V~~ and the pointed shape of the electrode, avalanche amplification ~~of electrons~~ occurs. The positive ions thus generated quickly drift toward strip-shaped cathode electrodes (14) around the ions. In the course of this process, electric charges are generated on the columnar anode electrodes and also on the strip-shaped cathodes, and these electric charges are observable ~~on the electric circuit. Therefore, observation~~ to determine the anode or cathode strip at which this amplification phenomenon occurs and thus to obtain ~~provides~~ information as to ~~about the~~ position of the incident particle beam.